fitipower

FR9854

18V, 4A Synchronous Step-Down DC/DC Converter

Description

The FR9854 is a synchronous step-down DC/DC converter with fast constant on time control technique (FCOT) that provides 4.5V to 18V input voltage range and 4A continuous load current capability. At light load condition, the FR9854 can operate at power saving mode to support high efficiency and reduce power loss.

The FR9854 fault protection includes cycle-by-cycle current limit, UVLO, short circuit protection and thermal shutdown. The soft-start function prevents inrush current at turn-on. The characteristics scheme of FR9854 are fast constant on time control which provides fast transient response, the noise immunity and all kinds of very low ESR output capacitor for ensuring performance stabilization.

The FR9854 is offered in SOP-8 (exposed pad) and TQFN-16 (3mm x 3mm) packages, which provides good thermal conductance.

Features

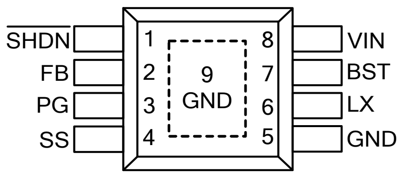
- Low $R_{DS(ON)}$ Integrated Power MOSFET (75mΩ/50mΩ)
- FCOT Mode Enables Fast Transient Response
- Wide Input Voltage Range: 4.5V to 18V
- 0.765V Reference Voltage (for FR9854SP Only)
- 0.8V Reference Voltage for (for FR9854W3 Only)
- 8V Maximum Output Voltage
- 4A Output Current
- 630kHz Pseudo Frequency
- Power Good Function
- Adjustable Soft-Start Function (for FR9854SP Only)
- Internal 1ms Soft-Start (for FR9854W3 Only)
- Cycle-by-Cycle Current Limit
- Over Temperature Protection with Auto Recovery
- Input Under Voltage Lockout
- Hiccup Short Circuit Protection
- SOP-8 Exposed Pad and TQFN-16 (3mm x 3mm) Packages

Applications

- STB (Set-Top-Box)
- LCD Display, TV
- Distributed Power System
- Networking, XDSL Modem

Pin Assignments

SP Package (SOP-8 Exposed Pad)



W3 Package (TQFN-16)(3mm x 3mm)

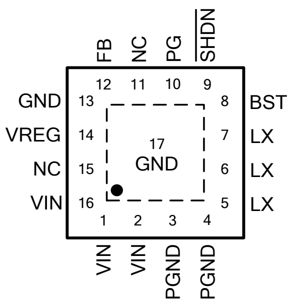


Figure 1. Pin Assignments of FR9854

Ordering Information

FR9854□

Package Type
SP: SOP-8 (Exposed Pad)
W3: TQFN-16 (3mm x 3mm)

Typical Application Circuit

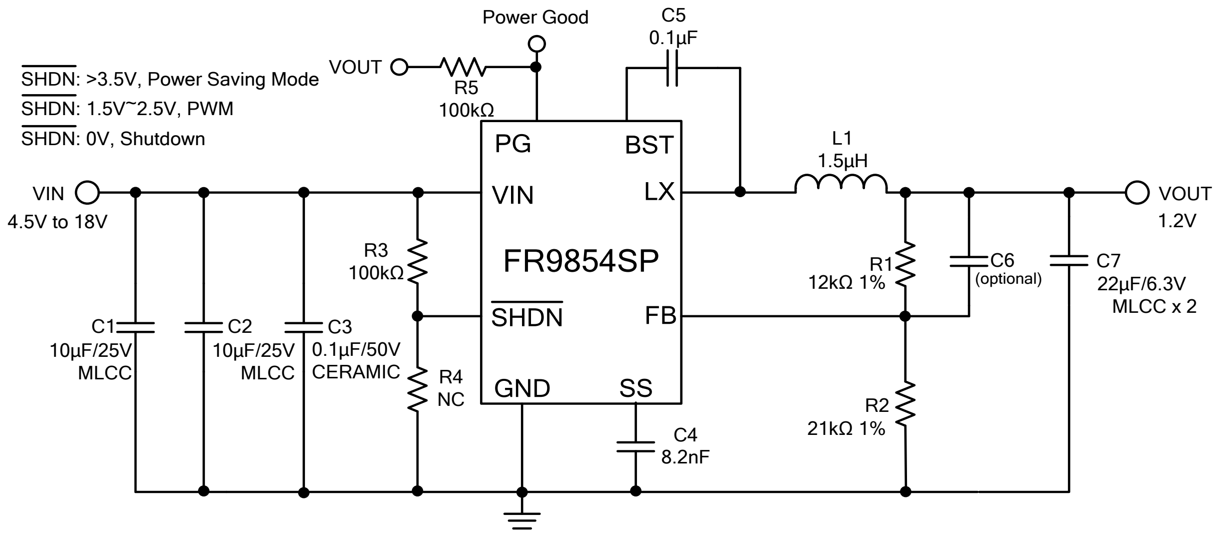


Figure 2. Application Circuit for SOP-8 Exposed Pad Package

V_{IN}=12V, the recommended BOM list is as below.

V_{OUT}	C1	R1	R2	C2	C6	L1	C7
1.05V	10μF MLCC	7.87kΩ	21kΩ	10μF MLCC	5pF~33pF	1.5μH	22μF MLCC x2
1.2V	10μF MLCC	12kΩ	21kΩ	10μF MLCC	5pF~33pF	1.5μH	22μF MLCC x2
1.8V	10μF MLCC	28kΩ	21kΩ	10μF MLCC	5pF~33pF	1.5μH	22μF MLCC x2
3.3V	10μF MLCC	69.8kΩ	21kΩ	10μF MLCC	5pF~33pF	2.2μH	22μF MLCC x2
5V	10μF MLCC	118kΩ	21kΩ	10μF MLCC	5pF~33pF	3.3μH	22μF MLCC x2

Table 1. Recommended Component Values

Typical Application Circuit (Continued)

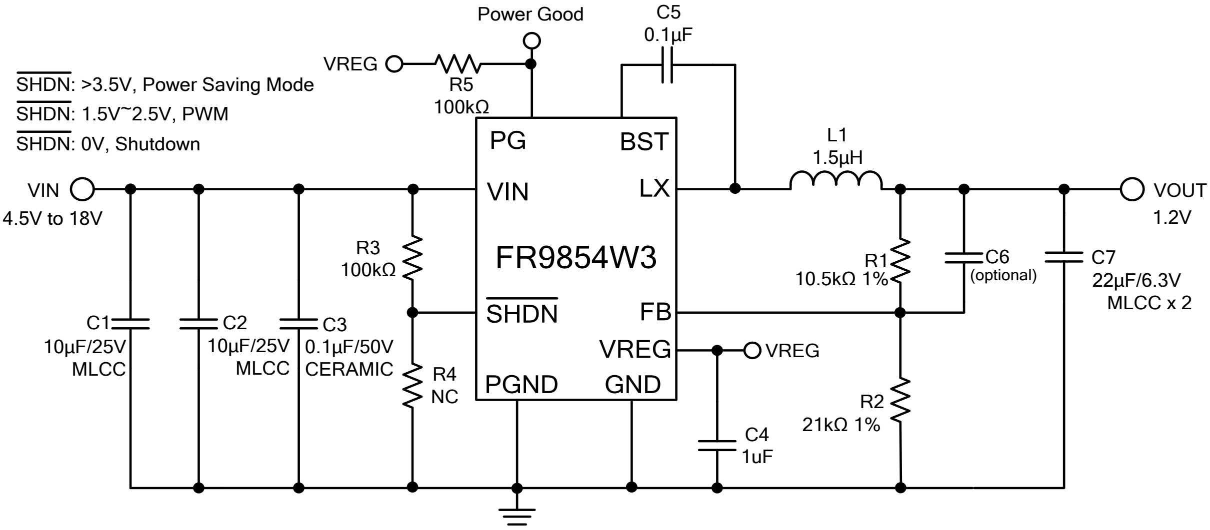


Figure 3. Application Circuit for TQFN-16 Package

V_{IN}=12V, the recommended BOM list is as below.

V_{OUT}	C1	R1	R2	C2	C6	L1	C7
1.05V	10µF MLCC	6.49kΩ	20.5kΩ	10µF MLCC	5pF~33pF	1.5µH	22µF MLCC x2
1.2V	10µF MLCC	10.5kΩ	21kΩ	10µF MLCC	5pF~33pF	1.5µH	22µF MLCC x2
1.8V	10µF MLCC	26.7kΩ	21kΩ	10µF MLCC	5pF~33pF	1.5µH	22µF MLCC x2
3.3V	10µF MLCC	71.5kΩ	22.6kΩ	10µF MLCC	5pF~33pF	2.2µH	22µF MLCC x2
5V	10µF MLCC	110kΩ	21kΩ	10µF MLCC	5pF~33pF	3.3µH	22µF MLCC x2

Table 2. Recommended Component Values

Functional Pin Description

Pin Name	Pin No. (SOP8-EP)	Pin No. (TQFN16-3x3)	Pin Function
SHDN	1	9	This pin includes enable the converter on/off, and select operation mode (The mode setting, please refer to the following page 10). Connect VIN with a 100kΩ resistor for self-startup and operate in power saving mode.
FB	2	12	Voltage feedback input pin. Connect FB and VOUT with a resistive voltage divider. This IC senses feedback voltage via FB and regulates voltage of FR9854SP is 0.765V and FR9854W3 is 0.8V.
PG	3	10	Open drain power good output.
SS	4	x	Soft-start pin. This pin controls the soft-start period. Connect a capacitor from SS to GND to set the soft-start period.
GND	5	13	Ground pin.
LX	6	5,6,7	Power switching node. Connect an external inductor to this switching node.
BST	7	8	High side gate drive boost pin. A capacitor rating between 0.1uF~1uF must be connected from this pin to LX. It can boost the gate drive to fully turn on the internal high side NMOS.
VIN	8	1,2,16	Power supply input pin. Placed input capacitors as close as possible from VIN to GND to avoid noise influence.
Exposed Pad	9	17	Ground pin. The exposed pad must be soldered to a large PCB area and connected to GND for maximum power dissipation.
PGND	x	3,4	Power ground pin.
VREG	x	14	Regulator output. Connect a 1uF capacitor to GND to stabilize the internal regulator voltage.

Block Diagram

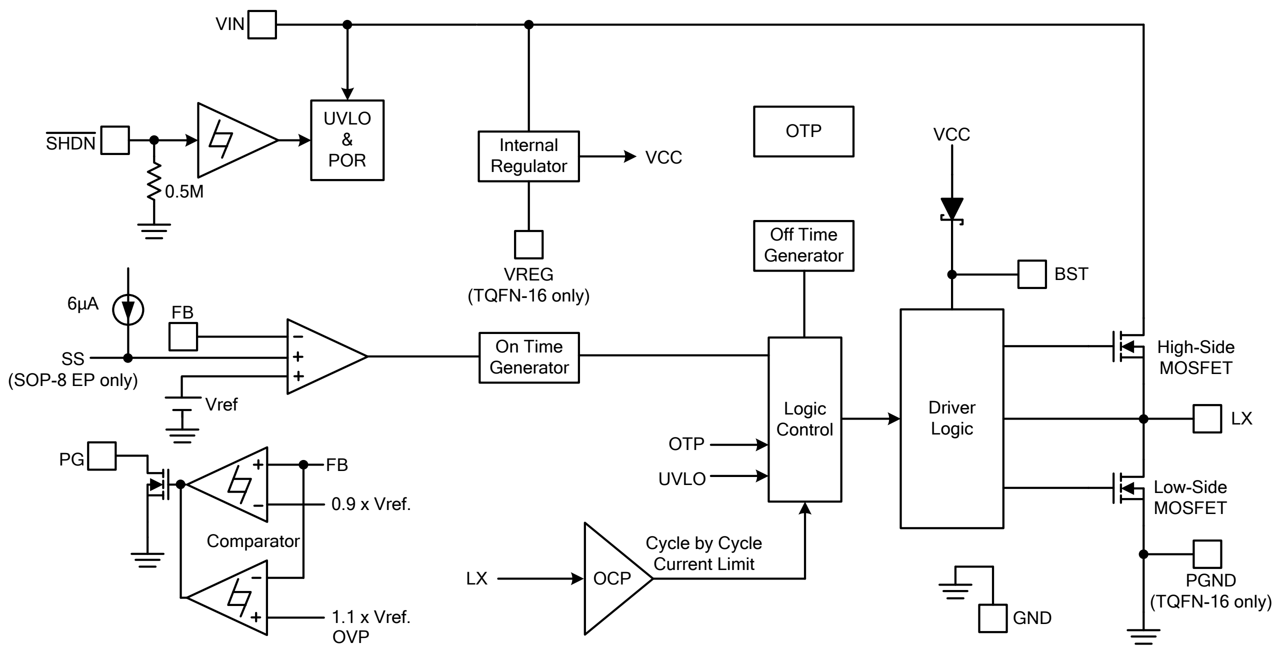


Figure 4. Block Diagram of FR9854

Absolute Maximum Ratings (Note 1)

- Supply Voltage V_{IN} ---------- -0.3V to +20V
- Enable Voltage $V_{\overline{SHDN}}$ ---------- -0.3V to +20V
- LX Voltage V_{LX} ---------- -0.3 to V_{IN} +0.3V
- Dynamic LX Voltage in 15ns Duration---------- -5V to V_{IN} +5V
- BST Pin Voltage V_{BST} ---------- -0.3V to V_{LX} +6.5V
- All Other Pins Voltage ---------- -0.3V to +6V
- Maximum Junction Temperature (T_J) ---------- +150°C
- Storage Temperature (T_S) ---------- -65°C to +150°C
- Lead Temperature (Soldering, 10sec.) ---------- +260°C
- Package Thermal Resistance, (θ_{JA}) (Note 2)
  - SOP-8 (Exposed Pad) ---------- 60°C/W
  - TQFN-16 (3mm x 3mm) ---------- 62°C/W
- Package Thermal Resistance, (θ_{JC}) (Note 2)
  - SOP-8 (Exposed Pad) ---------- 15°C/W
  - TQFN-16 (3mm x 3mm) ---------- 46°C/W

Note 1: Stresses beyond this listed under "Absolute Maximum Ratings" may cause permanent damage to the device.
Note 2: θ_{JA} is measured at TA=25°C on a high effective thermal conductivity 4-layer test PCB of JEDEC-51-7. θ_{JC} is measured at the exposed pad. The thermal resistance greatly varies with layout, copper thickness, number of layers and PCB size.

Recommended Operating Conditions

- Supply Voltage V_{IN} ---------- +4.5V to +18V
- Operating Ambient Temperature Range ---------- -40°C to +85°C
- Operating Junction Temperature Range ---------- -40°C to +125°C

Electrical Characteristics

(V_{IN}=12V, T_A=25°C, unless otherwise specified.)

Parameter	Symbol	Conditions		Min	Typ	Max	Unit
V_{IN} Quiescent Current	I_{DDQ}	$V_{\overline{SHDN}}$=5V, V_{FB}=1V			0.6	1	mA
V_{IN} Shutdown Supply Current	I_{SD}	$V_{\overline{SHDN}}$=0V			1	10	μA
Feedback Voltage	V_{FB}	4.5V≦V_{IN}≦18V	FR9854SP	0.75	0.765	0.78	V
			FR9854W3	0.788	0.8	0.812	
Feedback Input Current	I_{FB}	V_{FB}=1V			0.01	0.1	μA
High-Side MOSFET $R_{DS(ON)}$	$R_{DS(ON)}$				75		mΩ
Low-Side MOSFET $R_{DS(ON)}$	$R_{DS(ON)}$				50		mΩ
Current Limit (Note 3)	I_{LIMIT}				5.5		A
Low Side Current Limit (Note 3)	I_{LOW_LIMIT}	PWM mode			1.5		A
On Time (Note 3)	T_{ON}	V_{IN}=12V, V_{OUT}=1.05V			155		ns
Minimum Off Time	$T_{OFF(MIN)}$	V_{FB}=0.6V			250		ns
Input Supply Voltage UVLO Threshold	$V_{UVLO(Vth)}$	V_{IN} Rising			4.1		V
UVLO Threshold Hysteresis	$V_{UVLO(HYS)}$				0.35		V
Soft Start Charge Current	I_{SS}	V_{SS}=0V			6		μA
Internal Soft-Start Period	T_{SS}	FR9854W3			1		ms
$\overline{SHDN}$ Input Low Voltage	$V_{\overline{SHDN}(L)}$					0.5	V
$\overline{SHDN}$ Input High Voltage (Note 3)	$V_{\overline{SHDN}(H)}$			1.5			V
REG Output Voltage	V_{REG}	6V≦V_{IN}≦18V, FR9854W3			4.1		V
REG Output Current	I_{REG}	V_{REG}=4.1V, FR9854W3			10		mA
Under Voltage Detect Threshold	V_{UV}			0.36	0.4	0.44	V
Power Good Threshold (Note 3)	V_{PG}	V_{FB} Rising		85	90	95	%
		V_{FB} Falling			85		
Power Good Sink Current	I_{PG}	V_{PG}=0.5V			5		mA
Thermal Shutdown Threshold (Note 3)	T_{SD}				160		°C
Thermal Shutdown Hysteresis (Note 3)	T_{HYS}				30		°C

Note 3: Not production tested.

Typical Performance Curves

V_{IN}=12V, V_{OUT}=1.2V, C1=10μFx2, C7=22μFx2, L1=1.5μH, T_A=+25°C, unless otherwise noted.

V_{IN}=12V

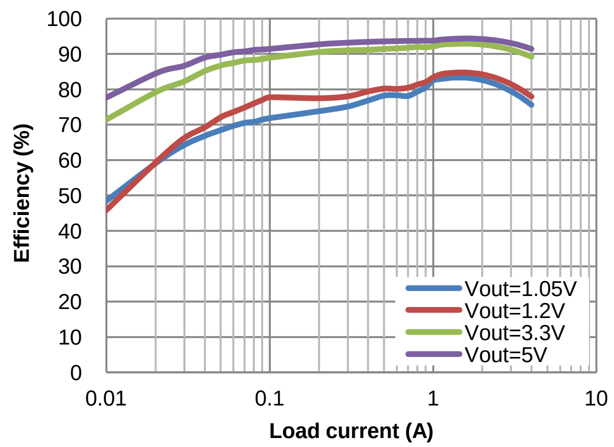


Figure 5. Efficiency vs. Load Current (FR9854SP)

V_{IN}=12V

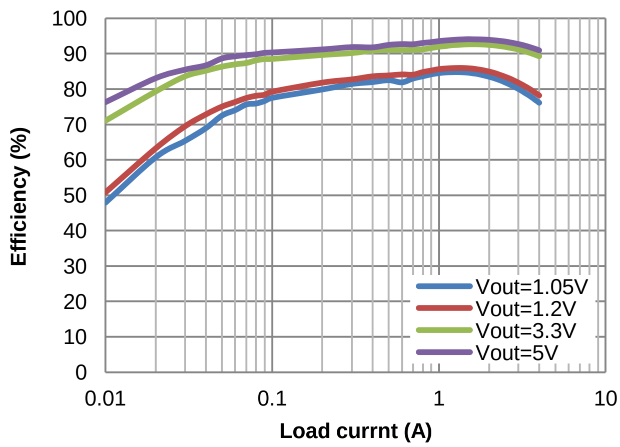


Figure 6. Efficiency vs. Load Current (FR9854W3)

V_{IN}=12V, $V_{\overline{SHDN}}$=2V

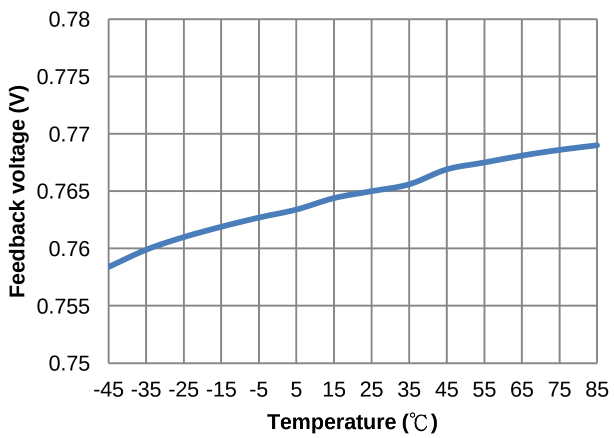


Figure 7. Feedback Voltage vs. Ambient Temperature (FR9854SP)

V_{IN}=12V, $V_{\overline{SHDN}}$=2V

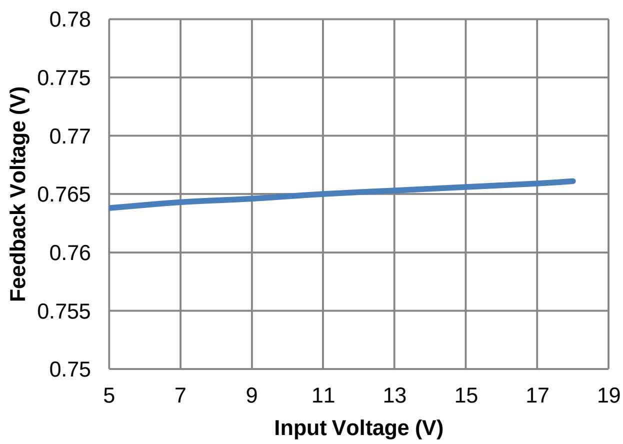


Figure 8. Feedback Voltage vs. Input Voltage (FR9854SP)

V_{IN}=12V, $V_{\overline{SHDN}}$=2V, V_{OUT}=1V, L=1.5μH

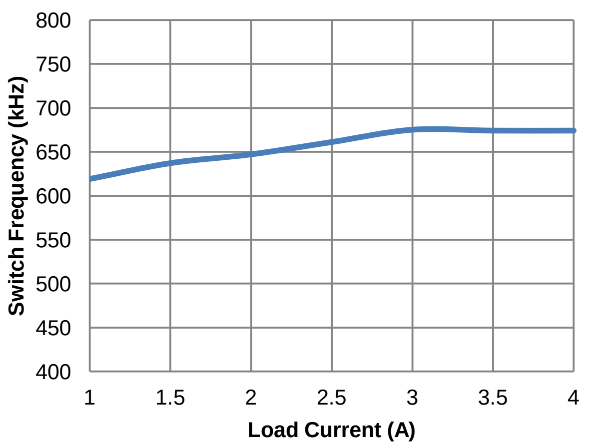


Figure 9. Switch Frequency vs. Load Current (FR9854SP)

V_{IN}=12V, $V_{\overline{SHDN}}$=2V, V_{OUT}=5V, L=3.3μH

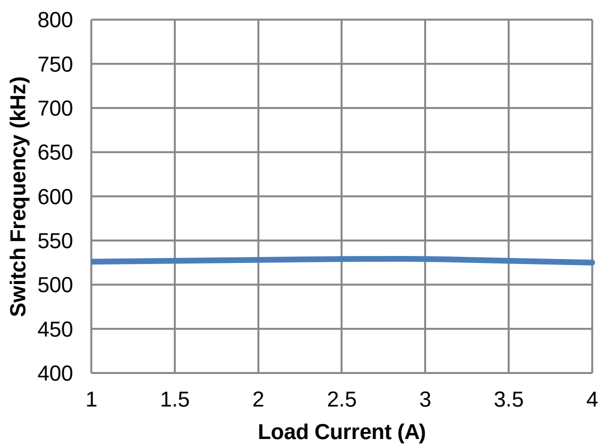


Figure 10. Switch Frequency vs. Load Current (FR9854SP)

Typical Performance Curves (Continued)

V_{IN}=12V, V_{OUT}=1.2V, C1=10μFx2, C7=22μFx2, L1=1.5μH, T_A=+25°C, unless otherwise noted. This is measured by using FR9854SP.

I_{OUT}=0A

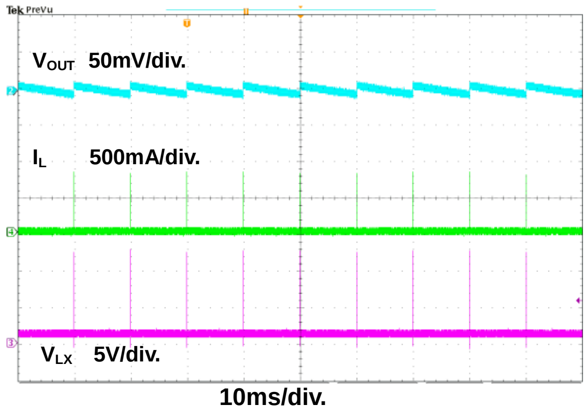


Figure 11. Steady State Waveform

I_{OUT}=4A

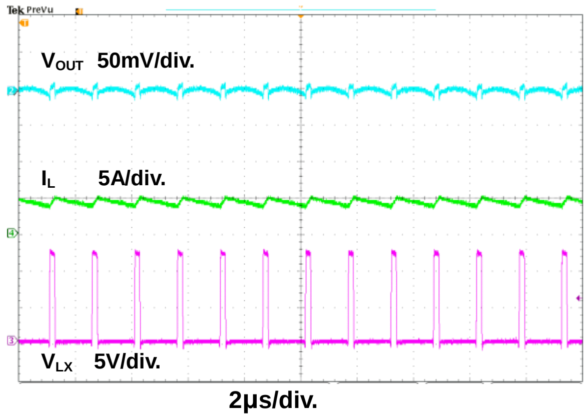


Figure 12. Steady State Waveform

I_{OUT}=0A

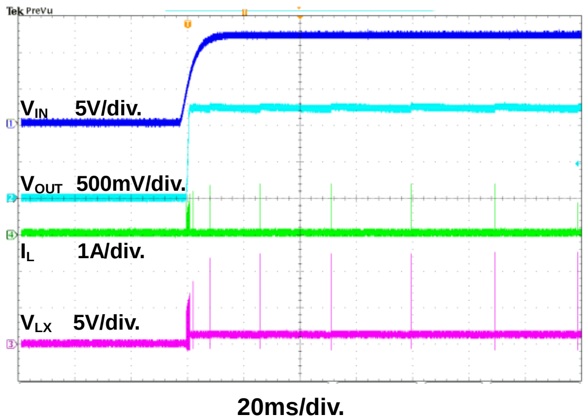


Figure 13. Startup Through Power Supply Waveform

I_{OUT}=4A

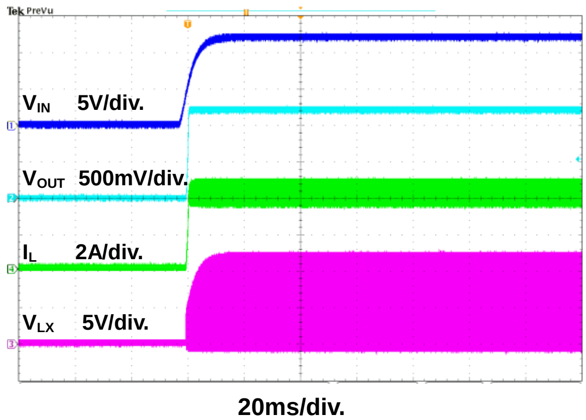


Figure 14. Startup Through Power Supply Waveform

I_{OUT}=0A

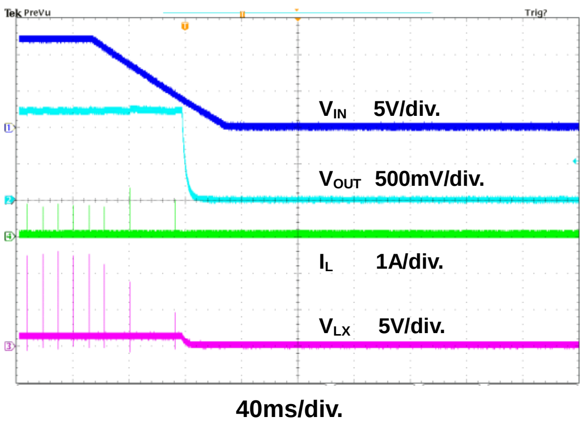


Figure 15. Shutdown Through Power Supply Waveform

I_{OUT}=4A

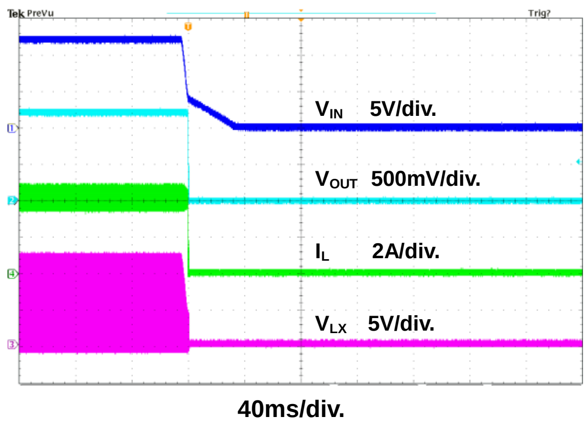


Figure 16. Shutdown Through Power Supply Waveform

Typical Performance Curves (Continued)

V_{IN}=12V, V_{OUT}=1.2V, C1=10μFx2, C7=22μFx2, L1=1.5μH, T_A=+25°C, unless otherwise noted. This is measured by using FR9854SP.

I_{OUT}=0A

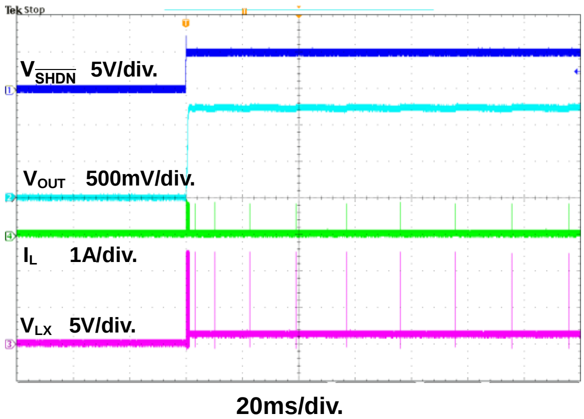


Figure 17. Startup Through $\overline{SHDN}$ Waveform

I_{OUT}=4A

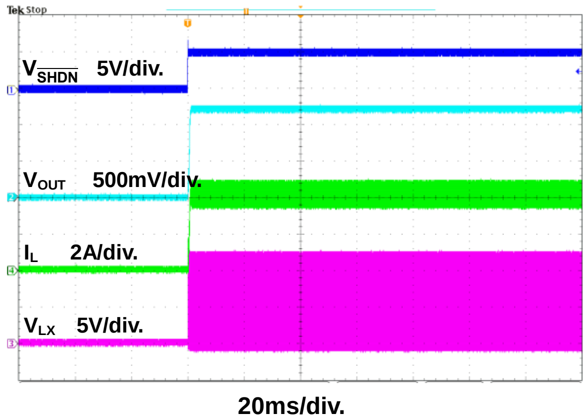


Figure 18. Startup Through $\overline{SHDN}$ Waveform

I_{OUT}=0A

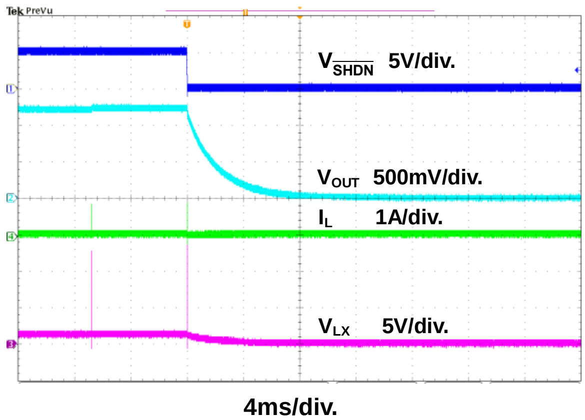


Figure 19. Shutdown Through $\overline{SHDN}$ Waveform

I_{OUT}=4A

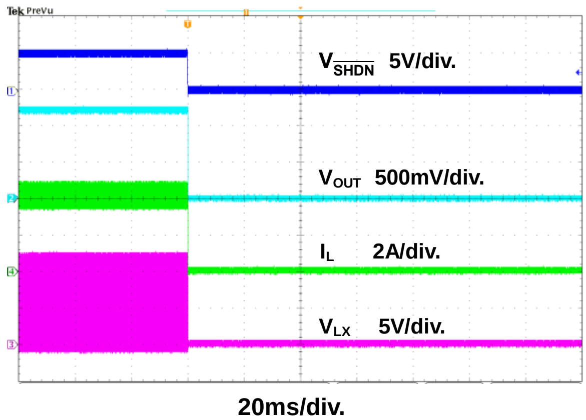


Figure 20. Shutdown Through $\overline{SHDN}$ Waveform

I_{OUT}=0.1A~4A

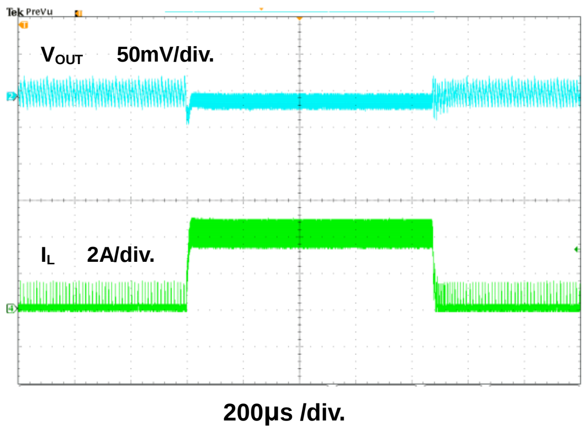


Figure 21. Load Transient Waveform

Function Description

The FR9854 is a high efficiency and fast constant on time control mode step-down synchronous DC/DC converter. It has integrated high-side (75mΩ, typ.) and low-side (50mΩ, typ.) power switches, and provides 4A continuous load current. It regulates input voltage from 4.5V to 18V, and maximum output voltage to 8V. Using FCOT control scheme provides fast transient response, which can minimize the component size without additional external compensation network.

Enable / Mode

The FR9854 $\overline{\text{SHDN}}$ pin includes enable and mode function. Enable function provides digital control to turn on/off the converter. When the voltage of $\overline{\text{SHDN}}$ exceeds the threshold voltage, the converter starts the soft start function. If the $\overline{\text{SHDN}}$ pin voltage is below than the shutdown threshold voltage, the converter will turn into the shutdown mode and the shutdown current will be smaller than 1μA. The mode function can be selected in PWM or power saving mode. The mode setting can refer to following table.

$\overline{\text{SHDN}}$	Mode
>3.5V	Power Saving Mode
1.5V~2.5V	PWM
0V	Shutdown

For auto start-up operation, connect $\overline{\text{SHDN}}$ to VIN through a 100kΩ resistor, and the converter can automatically enter power saving mode.

Soft Start

The FR9854 employs adjustable soft start function to reduce input inrush current during start up. When the device turns on, a 6μA current begins charging the capacitor which is connected from SS pin to GND. The equation for the soft start time is shown as below:

$$T_{SS}(ms)=\frac{C_{SS}(nF)\times V_{FB}}{I_{SS}(\mu A)}$$

If a capacitor with 8.2nF is connected from SS pin to GND, the soft-start time will be about 1ms.

Input Under Voltage Lockout

When the FR9854 is power on, the internal circuits are held inactive until V_{IN} voltage exceeds the input UVLO threshold voltage. And the regulator will be disabled when V_{IN} is below the input UVLO threshold voltage. The hysteretic of the UVLO comparator is 350mV (typ.).

Function Description (Continued)

Over Current Protection

The FR9854 over current protection function is implemented using cycle-by-cycle current limit architecture. The inductor current is monitored by Low-side MOSFET. When the load current increases, the inductor current also increases. When the valley inductor current reaches the current limit threshold, the output voltage starts to drop. When the over current condition is removed, the output voltage returns to the regulated value.

Short Circuit Protection

The FR9854 provides short circuit protection function to prevent the device damage from short condition. When the short condition occurs and the feedback voltage drops below 0.4V, the oscillator frequency will be reduce naturally and hiccup mode will be triggered to prevent the inductor current increasing beyond the current limit. Once the short condition is removed, the frequency will return to normal.

Low Side Current Limit

In PWM mode, the low side MOSFET will be turned on and the inductor current will inversely flow from output node to LX node when feedback voltage is larger than the reference voltage in certain situation. However, this inverse inductor current will destroy the low side MOSFET if this current is enough large. In order to avoid this problem, FR9854 would clamp this inverse current with 1.5A (typ.) until this situation is removed.

Over Temperature Protection

The FR9854 incorporates an over temperature protection circuit to protect itself from overheating. When the junction temperature exceeds the thermal shutdown threshold temperature, the regulator will be shutdown. And the hysteretic of the over temperature protection is 30°C (typ).

Power Good Signal Output (PG)

PG pin is an open-drain output and requires a pull up resistor. PG is actively held low in soft-start, standby, OVP and shutdown. It is released when the output voltage rises above 90% of nominal regulation point.

Output Over Voltage Protection

When the FB pin voltage exceeds 110%*V_{ref}, the output over voltage protection function will be triggered. The high-side/low-side MOSFET turn off and PG signal pull low.

Application Information

Output Voltage Setting

The output voltage V_{OUT} is set using a resistive divider from the output to FB. The reference voltage of FR9854SP is 0.765V and FR9854W3 is 0.8V. Thus the output voltage equation is:

$$V_{OUT}=0.765V\times\left(1+\frac{R1}{R2}\right)\rightarrow FR9854SP$$

$$V_{OUT}=0.8V\times\left(1+\frac{R1}{R2}\right)\rightarrow FR9854W3$$

Place resistors R1 and R2 close to FB pin to prevent stray pickup.

Input Capacitor Selection

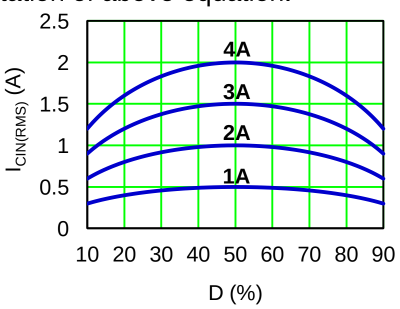
The use of the input capacitor is filtering the input voltage ripple and the MOSFETS switching spike voltage. Because the input current to the step-down converter is discontinuous, the input capacitor is required to supply the current to the converter to keep the DC input voltage. The capacitor voltage rating should be 1.25 to 1.5 times greater than the maximum input voltage. The input capacitor ripple current RMS value is calculated as:

$$I_{CIN(RMS)}=I_{OUT}\times\sqrt{D\times(1-D)}$$

$$D=\frac{V_{OUT}}{V_{IN}}$$

Where D is the duty cycle of the power MOSFET.

This function reaches the maximum value at D=0.5 and the equivalent RMS current is equal to $I_{OUT}/2$. The following diagram is the graphical representation of above equation.



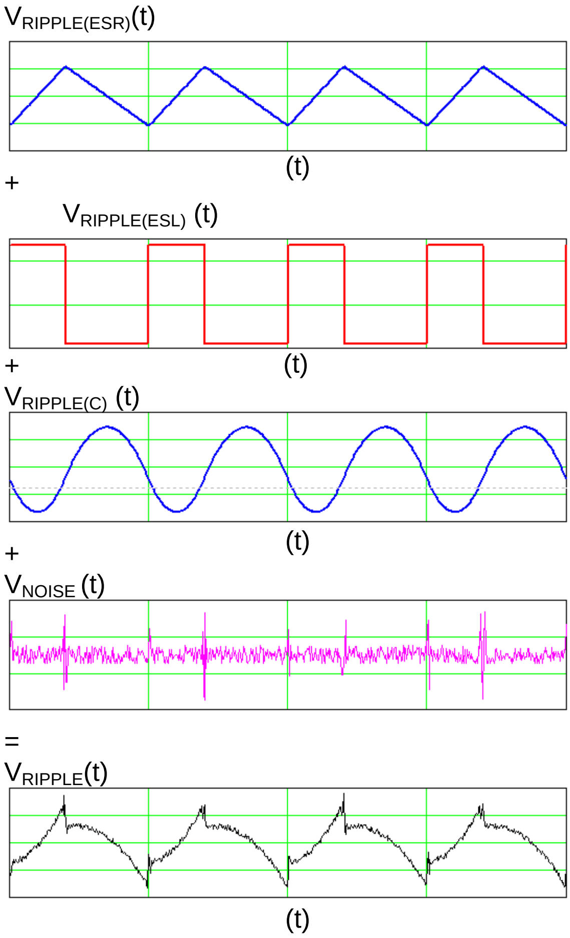
A low ESR capacitor is required to keep the noise minimum. Ceramic capacitors are better, but tantalum or low ESR electrolytic capacitors may also suffice. When using tantalum or electrolytic capacitors, a 0.1μF ceramic capacitor should be placed as close to the IC as possible.

Output Capacitor Selection

The output capacitor is used to keep the DC output voltage and supply the load transient current. When operating in constant current mode, the output ripple is determined by four components:

$$V_{RIPPLE}(t)=V_{RIPPLE(C)}(t)+V_{RIPPLE(ESR)}(t)+V_{RIPPLE(ESL)}(t)+V_{NOISE}(t)$$

The following figures show the form of the ripple contributions.



Application Information (Continued)

$$V_{RIPPLE(ESR)}=\frac{V_{OUT}}{F_{OSC}\times L}\times\left(1-\frac{V_{OUT}}{V_{IN}}\right)\times ESR$$

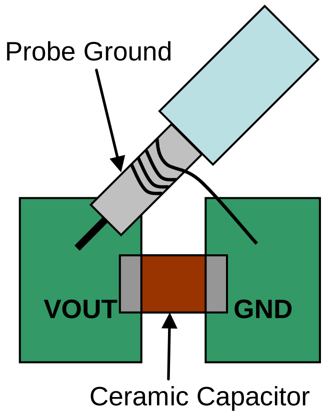
$$V_{RIPPLE(ESL)}=\frac{ESL}{L}\times V_{IN}$$

$$V_{RIPPLE(C)}=\frac{V_{OUT}}{8\times F_{OSC}^2\times L\times C_{OUT}}\times\left(1-\frac{V_{OUT}}{V_{IN}}\right)$$

Where F_{OSC} is the switching frequency, L is the inductance value, V_{IN} is the input voltage, ESR is the equivalent series resistance value of the output capacitor, ESL is the equivalent series inductance value of the output capacitor and the C_{OUT} is the output capacitor.

Low ESR capacitors are preferred to use. Ceramic, tantalum or low ESR electrolytic capacitors can be used depending on the output ripple requirement. When using the ceramic capacitors, the ESL component is usually negligible.

It is important to use the proper method to eliminate high frequency noise when measuring the output ripple. The figure shows how to locate the probe across the capacitor when measuring output ripple. Removing the scope probe plastic jacket in order to expose the ground at the tip of the probe. It gives a very short connection from the probe ground to the capacitor and eliminating noise.



Inductor Selection

The output inductor is used for storing energy and filtering output ripple current. But the trade-off condition often happens between maximum energy storage and the physical size of the inductor. The first consideration for selecting the output inductor is to make sure that the inductance is large enough to keep the converter in the continuous current mode.

That will lower ripple current and result in lower output ripple voltage. The ΔI_L is inductor peak-to-peak ripple current:

$$\Delta I_L=\frac{V_{OUT}}{F_{OSC}\times L}\times\left(1-\frac{V_{OUT}}{V_{IN}}\right)$$

A good compromise value between size and efficiency is to set the peak-to-peak inductor ripple current ΔI_L equal to 30% of the maximum load current. But setting the peak-to-peak inductor ripple current ΔI_L between 20%~50% of the maximum load current is also acceptable. Then the inductance can be calculated with the following equation:

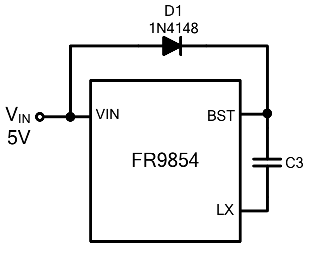
$$\Delta I_L=0.3\times I_{OUT(MAX)}$$

$$L=\frac{(V_{IN}-V_{OUT})\times V_{OUT}}{V_{IN}\times F_{OSC}\times\Delta I_L}$$

The inductor saturation current should be selected larger than the current limit of FR9854.

External Diode Selection

For 5V input applications, it is recommended to add an external boost diode. This helps improving the efficiency. The boost diode can be a low cost one such as 1N4148.



REG Capacitor Selection

Connect a 1uF ceramic capacitor between the REG and GND, This helps stabilize the internal regulator voltage.

Application Information (Continued)

PCB Layout Recommendation

The device's performance and stability is dramatically affected by PCB layout. It is recommended to follow these general guidelines shown as below:

1. Place the input capacitors and output capacitors as close to the device as possible. Trace to these capacitors should be as short and wide as possible to minimize parasitic inductance and resistance.
2. Place feedback resistors close to the FB pin.
3. Keep the sensitive signal (FB) away from the switching signal (LX).
4. The exposed pad of the package should be soldered to an equivalent area of metal on the PCB. This area should connect to the GND plane and have multiple via connections to the back of the PCB as well as connections to intermediate PCB layers. The GND plane area connecting to the exposed pad should be maximized to improve thermal performance.
5. Multi-layer PCB design is recommended.

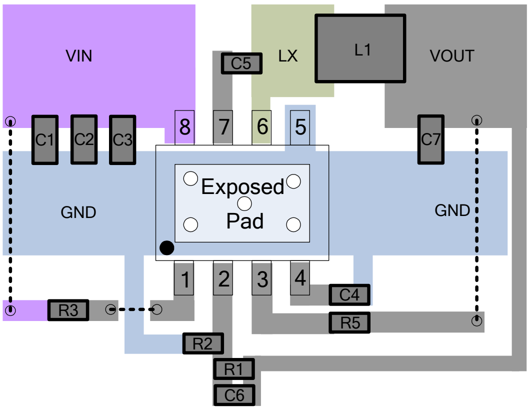


Figure 22. Recommended PCB Layout Diagram for SP Package

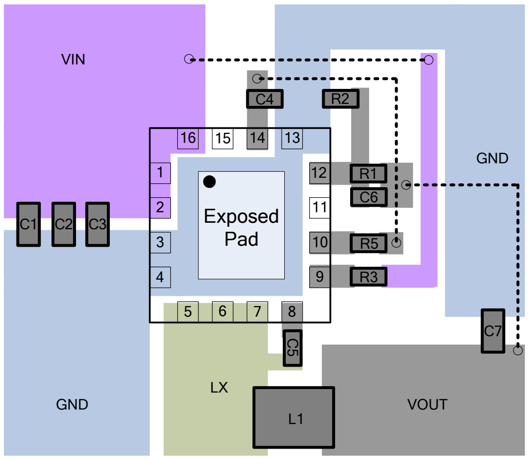
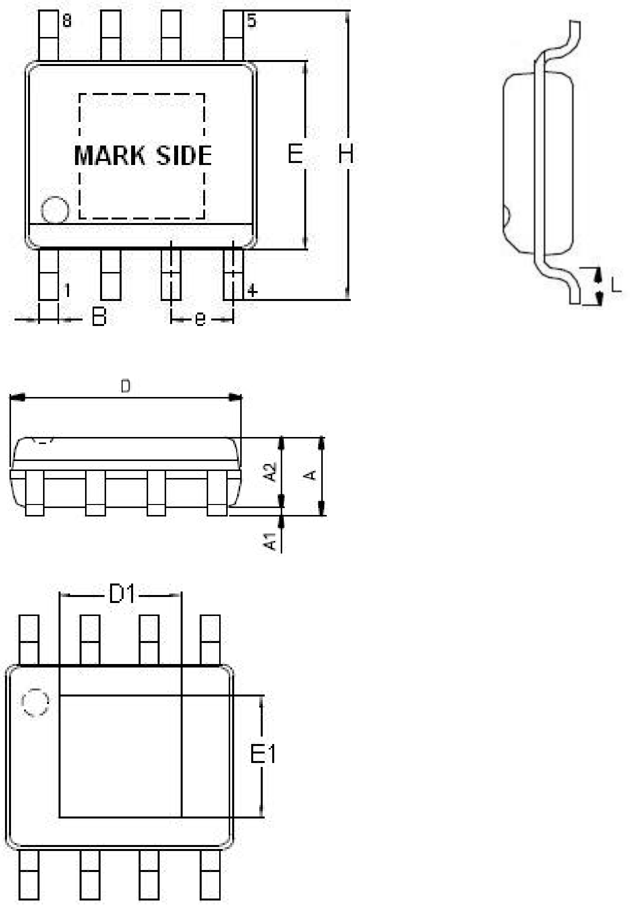


Figure 23. Recommended PCB Layout Diagram for W3 Package

Outline Information

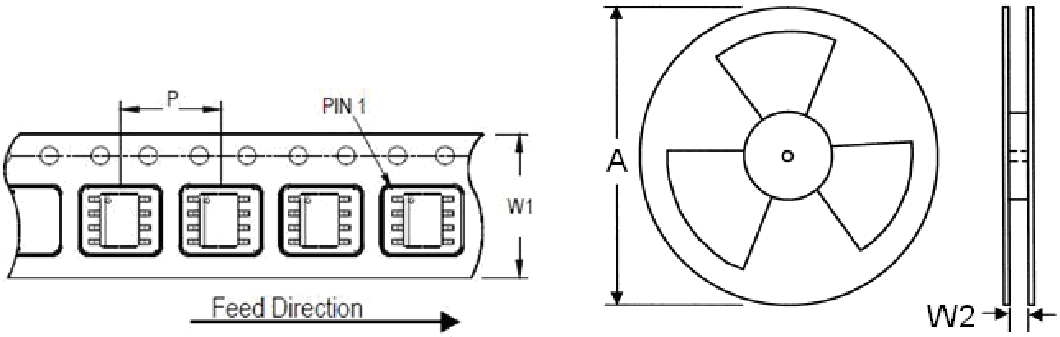
SOP-8 (Exposed Pad) Package (Unit: mm)



SYMBOLS UNIT	DIMENSION IN MILLIMETER	
	MIN	MAX
A	1.25	1.70
A1	0.00	0.15
A2	1.25	1.55
B	0.31	0.51
D	4.80	5.00
D1	3.04	3.50
E	3.80	4.00
E1	2.15	2.41
e	1.20	1.34
H	5.80	6.20
L	0.40	1.27

Note: Followed From JEDEC MO-012-E.

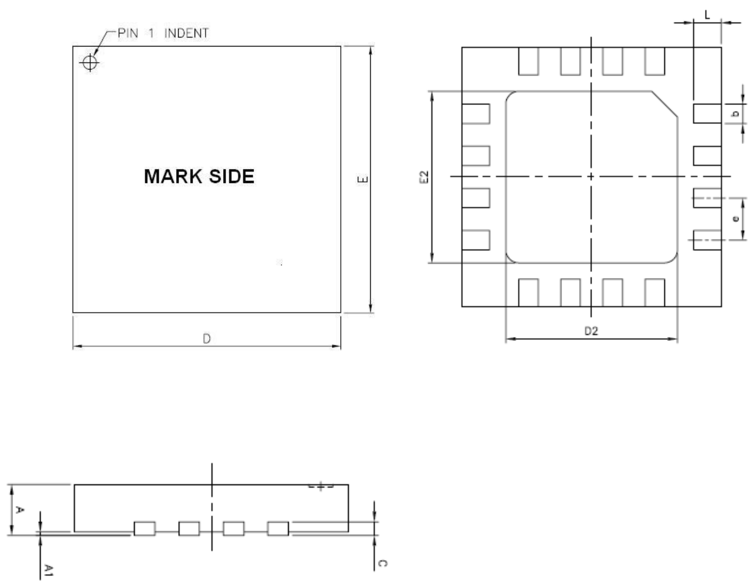
Carrier Dimensions



Tape Size (W1) mm	Pocket Pitch (P) mm	Reel Size (A)		Reel Width (W2) mm	Empty Cavity Length mm	Units per Reel
		in	mm			
12	8	13	330	12.4	400~1000	2,500

Outline Information (Continued)

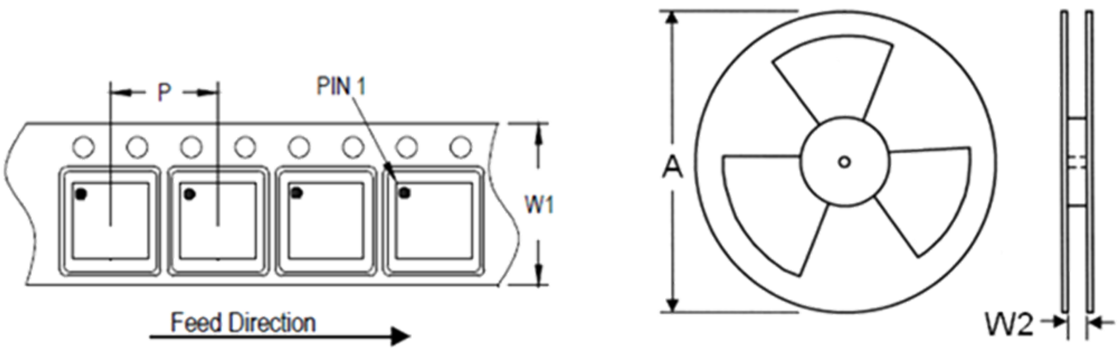
TQFN-16 3mm×3mm (pitch 0.5mm) Package (Unit: mm)



SYMBOLS UNIT	DIMENSION IN MILLIMETER	
	MIN	MAX
A	0.70	0.80
A1	0.00	0.05
C	0.19	0.30
E	2.90	3.10
D	2.90	3.10
L	0.35	0.45
b	0.18	0.30
e	0.45	0.55
E2	1.50	1.80
D2	1.50	1.80

Note: Followed From JEDEC MO-220.

Carrier dimensions



Tape Size (W1) mm	Pocket Pitch (P) mm	Reel Size (A)		Reel Width (W2) mm	Empty Cavity Length mm	Units per Reel
		in	mm			
12	8	13	330	12.4	400~1000	3,000

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Fitipower's products are not authorized for use as critical components in life support devices or other medical system.